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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of :

Ikuo KOHASHI :

Serial No. 09/777,922 : Group Art Unit: 2828

Filed February 7, 2001 : Examiner: Rodriguez, Armando

For: SEMICONDUCTOR LASER APPARATUS AND METHOD OF PRODUCING THE  
SAME

VERIFICATION OF ENGLISH TRANSLATION

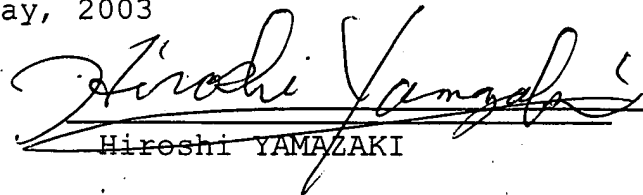
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Chuo-ku, Osaka 540-0001 Japan , declare that I am  
conversant in both the Japanese and English languages and  
that the English translation as attached hereto is accurate  
translation of Japanese Patent Application No. 2000-028554  
filed on February 7, 2000.

Signed this 30th day of May, 2003

  
Hiroshi YAMAZAKI

PATENT OFFICE  
JAPANESE GOVERNMENT

This is to certify that the annexed is a true copy  
of the following application as filed with this Office.

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Application Number: Patent Application No. 2000-028554

Applicant: SHARP KABUSHIKI KAISHA

December 22, 2000

Commissioner,

Patent Office Kozo OIKAWA

(Seal)

Document Name: Application for Patent  
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- 1 -

Document name: Specification

Title of the invention: SEMICONDUCTOR LASER APPARATUS AND  
METHOD OF PRODUCING THE SAME

What is claimed is:

1. A semiconductor laser apparatus having a semiconductor laser chip die-bonded to a predetermined position of a die-bonding surface, such as of a lead frame, a stem or a sub-mount, with a conductive die-bonding paste,

wherein a position at which the conductive die-bonding paste adheres to the semiconductor laser chip is at a height of more than 0.01 mm from the predetermined bonding surface, but is below the light-emitting point of the semiconductor laser chip.

2. A method of producing a semiconductor laser apparatus having a semiconductor laser chip die-bonded to a predetermined position of a die-bonding surface, such as of a lead frame, a stem or a sub-mount, with a conductive die-bonding paste, said method comprising the steps of:

applying the conductive die-bonding paste to the predetermined position thereof; and

preheating the applied conductive die-bonding paste and then placing the semiconductor laser chip on the preheated conductive die-bonding paste.

3. A method according to claim 2, wherein a temperature at which the conductive die-bonding paste is preheated is equal to or higher than a temperature at which a diluent of the conductive die-bonding paste starts to transpire,

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but not exceeding a temperature at which the conductive die-bonding paste starts a thermosetting reaction.

4. A method according to claim 2 or 3, wherein said conductive die-bonding paste contains an epoxy resin as a base material and is preheated at a temperature of 60°C or more but 80°C or less.

Detailed explanation of the invention:

[0001]

Technical field to which the invention pertains:

The present invention generally relates to semiconductor laser apparatuses and a method of producing them and more particularly, to a semiconductor laser apparatus having a semiconductor laser chip die-bonded with a conductive die-bonding paste and a method of producing it.

[0002]

Prior art:

As disclosed in Japanese Patent Application Laid-Open No. 6-37403, in conventional semiconductor laser apparatuses, a semiconductor laser chip is die-bonded to a predetermined position of a bonding surface, such as of a lead frame, a stem, or a sub-mount disposed on the stem, through a metal soldering material such as In, Pb/Sn (solder), Au/Sn or the like.

[0003]

For example, Fig. 5 shows a semiconductor laser apparatus of a first conventional embodiment of the present invention in a state that a semiconductor laser chip 50 is bonded

in a predetermined position of a die-bonding surface 51a of a sub-mount 51 with a metal soldering material 52. The metal soldering material 52 is a solid at the room temperature, and is deposited to the bonding surface in the predetermined bonding position by evaporation or the like. After the semiconductor laser chip 50 is placed on the metal soldering material 52, the metal soldering material 52 is heated to 150°C or higher to melt. At this time, the semiconductor laser chip 50 is immobilized with a bonding collet or the like (not shown). Finally, the metal soldering material 52 is cooled to harden or set. Thus, the semiconductor laser chip 50 is die-bonded to the predetermined position of the die-bonding surface 51a. In Fig. 5, reference numeral 53 denotes a main-discharge-side light-emitting point of the semiconductor laser chip 50, reference numeral 54 denotes a monitoring sub-discharge-side light-emitting point of the semiconductor laser chip 50, and reference numeral 55 denotes an emission light axis of the semiconductor laser chip 50 connecting the main-discharge-side light-emitting point and the sub-discharge-side light-emitting point to each other.

[0004]

Problem to be solved by the invention:

In the method of producing the conventional semiconductor laser apparatus of the first conventional embodiment shown in Fig. 5, the melting point of the metal soldering material 52 is high. Thus, there was a problem in that the heating/cooling cycle took much time and thus it took



long to produce the semiconductor laser apparatus. Further, the hardened metal soldering material 52 is thinner than 0.01 mm. Thus, if the semiconductor laser apparatus of the first conventional embodiment is adopted for an optical pick-up using a three-beam scheme which is a dominant tracking control method, the following problem occurs. Of the three beams which have returned from an optical disk, one auxiliary beam is regularly reflected off a discharge surface of the semiconductor laser chip 50 back to the optical disk, and is then incident on a signal detection photodiode to generate noise.

[0005]

As a measure of overcoming the problem that it takes long to make the semiconductor laser apparatus, there is proposed a method (hereinafter referred to as second conventional embodiment) of making a semiconductor laser apparatus. In the method, the semiconductor laser chip is die-bonded to a bonding surface with a conductive die-bonding paste (conductive adhesive agent) instead of the metal soldering material. The conductive die-bonding paste contains resin and a conductive filler such as silver flakes. It is possible to lower the hardening temperature of the conductive die-bonding paste to about 100°C, depending on the resin to be used. Accordingly, the heating/cooling cycle becomes short. Thus it is possible to reduce the time required to produce the semiconductor laser apparatus.

[0006]

Fig. 6 shows a semiconductor laser apparatus formed

by die-bonding a semiconductor laser chip to a die-bonding surface with a conductive die-bonding paste. In Fig. 6, reference numeral 50 denotes the semiconductor laser chip, reference numeral 51 denotes a stem, reference numeral 51a denotes the die-bonding surface, reference numeral 53 denotes a main-discharge-side light-emitting point, reference numeral 54 denotes a monitoring sub-discharge-side light-emitting point, reference numeral 55 denotes an emission light axis of the semiconductor laser chip 50 connecting the main-discharge-side light-emitting point and the sub-discharge-side light-emitting point to each other, and reference numeral 56 denotes a conductive die-bonding paste.

[0007]

However, in the method of producing the semiconductor laser apparatus according to the second conventional embodiment, when the proportion of the conductive filler is increased to reduce the electric resistance of the conductive die-bonding paste 56, the viscosity of the conductive die-bonding paste 56 becomes high. Consequently, when a semiconductor laser chip 50 is placed on the conductive die-bonding paste 56, the conductive die-bonding paste 56 swells and adheres to the end surfaces and side surfaces of the semiconductor laser chip 50, and blocks the main-discharge-side light-emitting point 53 and/or the monitoring sub-discharge-side light-emitting point 54. This will be concretely described below with reference to Fig. 7.

[0008]

Referring to Fig. 7(a), a predetermined slight amount of the conductive die-bonding paste 56, which has been discharged from a dispenser (not shown), is on a tip of a syringe needle 57. With a downward movement of the tip of the syringe needle 57 in a descending direction 58A, the conductive die-bonding paste 56 is placed in a predetermined position of a die-bonding surface 51a of a sub-mount 51. Then, with the tip of the syringe needle 57 moved in an ascending direction 58B as shown in Fig. 7(b), the conductive die-bonding paste 56 is applied to a predetermined part of the die-bonding surface 51a of the sub-mount 51.

[0009]

Then, as shown in Fig. 6, the semiconductor laser chip 50 is placed on the conductive die-bonding paste 56 applied to the die-bonding surface 51a of the sub-mount 51. The size of the lower surface of the semiconductor laser chip 50 is about 0.2 mm x 0.2 mm, and the light-emitting point is located at about 0.05 mm from the lower surface of the semiconductor laser chip 50. That is, the light-emitting point is at a level higher than the semiconductor laser chip mounting surface 51a by about 0.05 mm. On the other hand, from the viewpoint of reliably applying the conductive die-bonding paste 56 to the die-bonding surface 51a, it is impossible to make the diameter of the tip of the syringe needle 57 smaller than about 0.3 mm. Consequently, the application area of the conductive die-bonding paste 56 is wider than the size of the semiconductor laser chip 50, and the thickness of the conductive die-bonding paste 56 frequently

exceeds 0.05 mm. Accordingly, as shown in Fig. 6, the conductive die-bonding paste 56 swells along the end surfaces and side surfaces of the semiconductor laser chip 50 mounted thereon. The end surfaces have the main discharge-side light-emitting point 53 and the monitoring light-emitting point 54, respectively. Thus, if the conductive die-bonding paste 56 is heated and cooled to harden in the above state, it follows that the conductive die-bonding paste 56 blocks the main-discharge-side light-emitting point 53 and the monitoring light-emitting point 54.

[0010]

Means of solving the problem:

The present invention has been made to solve the problems. Therefore, it is an object of the present invention to provide a semiconductor laser apparatus which hardly generates noise even when it is used for a pick-up using a three-beam scheme.

[0011]

It is another object of the present invention to provide a method of producing a semiconductor laser apparatus, which method does not cause the disadvantage that a conductive die-bonding paste, if used, blocks a main discharge-side light-emitting point and a monitoring-side light-emitting point.

[0012]

According to an aspect of the invention, there is provided a semiconductor laser apparatus having a semiconductor

laser chip die-bonded to a predetermined position of a die-bonding surface, such as of a lead frame, a stem or a sub-mount, with a conductive die-bonding paste,

wherein a position at which the conductive die-bonding paste adheres to the semiconductor laser chip is at a height of more than 0.01 mm from the predetermined bonding surface, but is below the light-emitting point of the semiconductor laser chip.

[0013]

With this arrangement, a semiconductor laser apparatus that does not generate noise is provided, even if it is adopted in an optical pick-up using a three-beam scheme.

There is also provided a method of realizing a semiconductor laser apparatus having the above structure, said method comprising the steps of:

applying a conductive die-bonding paste to a predetermined position of a die-bonding surface; and

preheating the applied conductive die-bonding paste and then placing the semiconductor laser chip on the preheated conductive die-bonding paste.

[0014]

In one embodiment, a lower limit of a temperature at which the conductive die-bonding paste is preheated is set to a temperature at which a diluent of the conductive die-bonding paste starts to transpire, and an upper limit thereof is set to a temperature at which the conductive die-bonding paste starts a thermosetting reaction.

[0015]

With this arrangement, even if a semiconductor laser apparatus is made using the conductive die-bonding paste, the disadvantage that the conductive die-bonding paste blocks the main discharge-side light-emitting point and the monitoring-side light-emitting point is not caused.

[0016]

In one embodiment, the conductive die-bonding paste containing an epoxy resin as a base material is used and is preheated at a temperature of 60°C or more but 100°C or less.

[0017]

With this arrangement, even if the conductive die-bonding paste is used, it is possible to make a semiconductor laser apparatus, which does not cause the disadvantage that the conductive die-bonding paste blocks the main discharge-side light-emitting point and the monitoring-side light-emitting point, more easily.

[0018]

Mode for carrying out the invention:

Fig. 3 shows a part of a semiconductor laser apparatus of an embodiment of the present invention in which a semiconductor laser chip 5 is die-bonded to a stem 1. The method of producing the semiconductor laser apparatus will be described below with reference to Fig. 1 and Fig. 2.

[0019]

Referring first to Fig. 1, the stem 1 is formed by working a base metal of an iron alloy or copper alloy and then

applying a surface-treatment, such as gilding, to the worked piece. Similarly to the conventional art, a conductive die-bonding paste 2 is applied to a predetermined position of a die-bonding surface 1a of the stem 1. That is, a predetermined slight amount of the conductive die-bonding paste 2, which has been ejected to a tip 3 of a syringe needle by a dispenser (not shown), is applied to the stem 1, as shown in Fig. 1(b), through a downward movement indicated by arrow 4A and an upward movement indicated by arrow 4B of the syringe needle tip 3.

[0020]

The conductive die-bonding paste 2 to be used in the semiconductor laser apparatus of the embodiment contains an epoxy resin as a base material and 80 wt% or more conductive filler such as silver flakes. Fig. 4 shows an example of the temperature-dependency of TG and DTA of the conductive die-bonding paste 2. In Fig. 4, the axis of abscissas represents time, and Fig. 4 indicates that after the elapse of about five minutes, temperature rises in proportion to time. The temperature corresponding to a point ① at which the TG starts to drop is a temperature at which a diluent starts to transpire. Also, the temperature corresponding to a point ② at which the DTA curve starts to rise is a temperature at which a thermosetting reaction starts. Fig. 4 indicates that the temperature at which the diluent starts to transpire is about 60°C and that the temperature at which the thermosetting reaction starts is about 100°C.

[0021]

Then the stem 1 is preheated at about 70° which is lower than the temperature at which the conductive die-bonding paste 2 applied to the stem 1 starts the thermosetting reaction. The conductive die-bonding paste 2 is high in viscosity and swells like a drop of water immediately after it has been applied to the stem 1, as shown in Fig. 2. The preheating reduces the viscosity of the conductive die-bonding paste 2. The conductive die-bonding paste 2 diffuses to form a preheated thin conductive die-bonding paste 20. The preheating is performed until the thickness of the preheated conductive die-bonding paste 20 becomes as thin as about 0.02 mm. The shorter the preheating time is, the higher the productivity is. However, it is preferable to preheat the stem 1 for two seconds or more in consideration of its heat capacity.

[0022]

The temperature at which the conductive die-bonding paste 2 starts the thermosetting reaction is 100°C. However, if the preheating temperature is set to higher than 80°C, the transpiration speed of the diluting agent will be high. Thus, depending on a preheating time period, a problem in that the conductive die-bonding paste hardens partly may take place. On the other hand, if the preheating temperature is lower than 60°C, the viscosity of the conductive die-bonding paste is not reduced because the thermosetting reaction does not take place. Accordingly, it is preferable to set the preheating temperature range to 60 - 80°C.

[0023]



With the semiconductor laser chip 5 mounted on the preheated conductive die-bonding paste 20, the conductive die-bonding paste 20 is heated to a temperature higher than the temperature at which the thermosetting reaction starts, whereby the conductive die-bonding paste 20 is fully hardened or set. In this manner, the semiconductor laser apparatus shown in Fig. 3 is obtained. In this method, the preheated conductive die-bonding paste 20 does not swell or rise above a main-discharge-side light-emitting point 6 nor a monitoring-side light-emitting point 7 of the semiconductor laser chip 5 (each light-emitting point is at a height of about 0.05 mm).

[0024]

The proper hardening process takes much time. Therefore, it is preferable to heat the conductive die-bonding paste 2 for a short time on a die-bonding device to harden the paste to such an extent that the paste does not move when the semiconductor laser chip 5 is subjected to a slight shock, and then transfer the conductive die-bonding paste 2 to a different place to harden it completely.

[0025]

The height of the preheated conductive die-bonding paste 20 from the mounting surface 1a for the semiconductor laser chip 5 is more than 0.01 mm. In an optical pick-up using the three-beam scheme, three beams (not shown) returning from an optical disk (not shown) enter an end surface of the semiconductor laser chip 5, with the three beams spaced from each other in a direction approximately perpendicularly to the

die-bonding surface 1a at intervals of about 50  $\mu\text{m}$ . Thus, in the use of the semiconductor laser apparatus of the embodiment, of the three beams (not shown), the main beam returns to the light-emitting point, whereas one auxiliary beam travels above the semiconductor laser chip 5 and the other auxiliary beam is scattered by the conductive die-bonding paste 20 and is not regularly reflected on the discharge surface of the semiconductor laser chip 5. That is, the auxiliary beams do not return to an optical detector (not shown). Thus, no noise is generated.

[0026]

The conductive die-bonding paste used in the embodiment contains an epoxy resin as a base material and a conductive filler such as silver flakes, the content of the latter being 80 wt% or more. The resin to be used as a base material is not limited to the epoxy resin, but silicone resin or polyimide resin may be used. However, because the polyimide resin has a high thermosetting temperature, it takes much time to harden it. Thus, there is a problem in that the polyimide resin may give a bad influence on other materials and so on. On the other hand, because the silicone resin is still soft after it was set or hardened, there is a possibility that the die-bonding position of the semiconductor laser chip and its orientation may be shifted by an external shock which may be given to the hardened silicone resin. With the shift of the die-bonding position of the semiconductor laser chip and its orientation, the optical axis of the semiconductor laser chip

is displaced with respect to that of an optical system of an optical disk system for which the semiconductor laser apparatus is used. Therefore, there is a problem in that information of the optical disk cannot be read.

[0027]

On the other hand, in the conductive die-bonding paste containing the epoxy resin as a base material, there is little difference in the shape of the conductive die-bonding paste between before and after it sets or hardens. Thus, in hardening the conductive die-bonding paste, the position and orientation of the semiconductor laser chip are prevented from being changed. Consequently, when the semiconductor laser apparatus of the embodiment is used for an optical pick-up, it is easy to correctly set the positional relationship between the semiconductor laser apparatus and other optical elements of the optical pick-up.

[0028]

The semiconductor laser apparatus of the embodiment and the method of producing it has been described on the case in which the semiconductor laser chip is directly mounted on the stem. But apparently, the present invention is also applicable to a case in which the semiconductor laser chip is mounted on a sub-mount made of ceramic, silicon or the like, and the sub-mount with the chip is then mounted on a stem, and also to a case in which the semiconductor laser chip is mounted on a lead frame.

[0029]

Although the dispensing method has been described as the conductive die-bonding paste application method, a stamping method may be used.

[0030]

Effect of the invention:

As described above, when the semiconductor laser apparatus of the present invention is used for the optical pick-up using the three-beam scheme, the conductive die-bonding paste does not cause regular reflection of the auxiliary beams. Thus, no noise is generated.

[0031]

Further, because the semiconductor laser apparatus is assembled with the conductive die-bonding paste, it is possible to shorten a heating/cooling time period. Further, because the heating temperature is low, other component parts of the semiconductor laser apparatus are not affected thereby. Furthermore, the problem in that the conductive die-bonding paste obstructs the main-discharge-side light-emitting point or the monitoring-side light-emitting point does not take place, because after the conductive die-bonding paste is dispensed to the predetermined position, it is preheated to reduce its viscosity. This in particular allows use of a conductive die-bonding paste that contains much conductive filler and thus has a low electric resistance. Therefore, it is preferably used to die-bond a semiconductor laser chip to which a large current is applied.

[0032]

Further, in the semiconductor laser apparatus production method of the present invention, owing to the use of the conductive die-bonding paste containing the epoxy resin as a base material, the die-bonding position of the semiconductor laser chip and its orientation do not shift when the conductive die-bonding paste is hardened. Therefore, after the conductive die-bonding paste is hardened, the mounted position of the semiconductor laser chip and its orientation hardly shift, because the resin is hard. Accordingly, it is easy to correctly set the positional relationship between the semiconductor laser apparatus and other optical elements when the semiconductor laser apparatus is used for the optical pick-up.

Brief explanation of the drawings:

Fig. 1 shows a process step for producing a semiconductor laser apparatus of an embodiment of the present invention, (a) showing a state prior to application of die-bonding paste, and (b) showing a state after the application of the die-bonding paste;

Fig. 2 shows a process step subsequent to the process step of Fig. 1 for producing the semiconductor laser apparatus of the embodiment of the present invention, (a) showing a state prior to performing a pre-hardening process, and (b) shows a state in which the pre-hardening has been performed;

Fig. 3 shows a part of the semiconductor laser apparatus of the embodiment of the present invention in which

a semiconductor laser chip has been die-bonded to a stem;

Fig. 4 shows the temperature-dependency of TG and DTA of a conductive die-bonding paste for use in producing the semiconductor laser apparatus of the embodiment of the present invention, the paste containing epoxy resin as a base material;

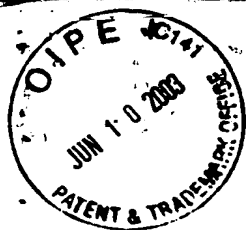
Fig. 5 shows a part of a semiconductor laser apparatus, according to a first conventional embodiment, in which a semiconductor laser chip is die-bonded to a stem;

Fig. 6 shows a part of a semiconductor laser apparatus, according to a second conventional embodiment, in which a semiconductor laser chip is die-bonded to a stem; and

Fig. 7 shows a process step for producing the semiconductor laser apparatus of the second conventional embodiment, (a) showing a state prior to application of die-bonding paste, and (b) showing a state after the application of the die-bonding paste.

Explanation of numerals:

- |       |  |
|-------|--|
| 1     | stem                                     |
| 2, 20 | conductive die-bonding paste             |
| 5     | semiconductor laser chip                 |
| 6     | main-discharge-side light-emitting point |
| 7     | monitoring-side light-emitting point     |

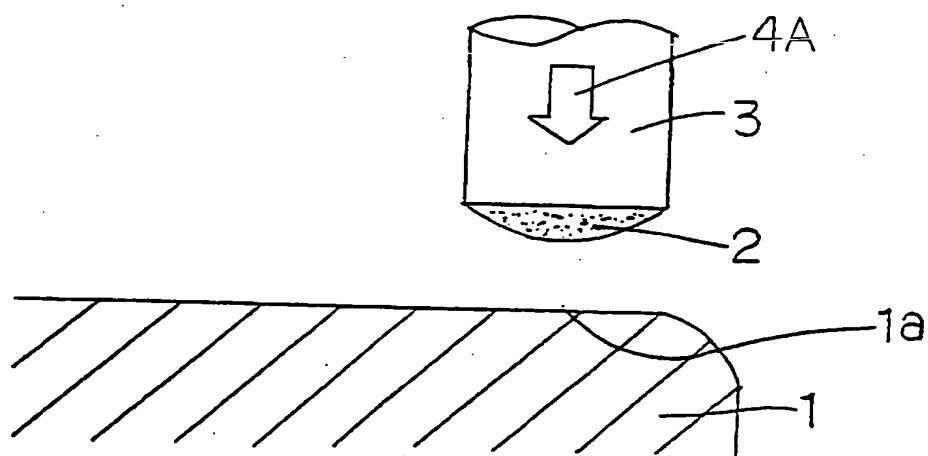


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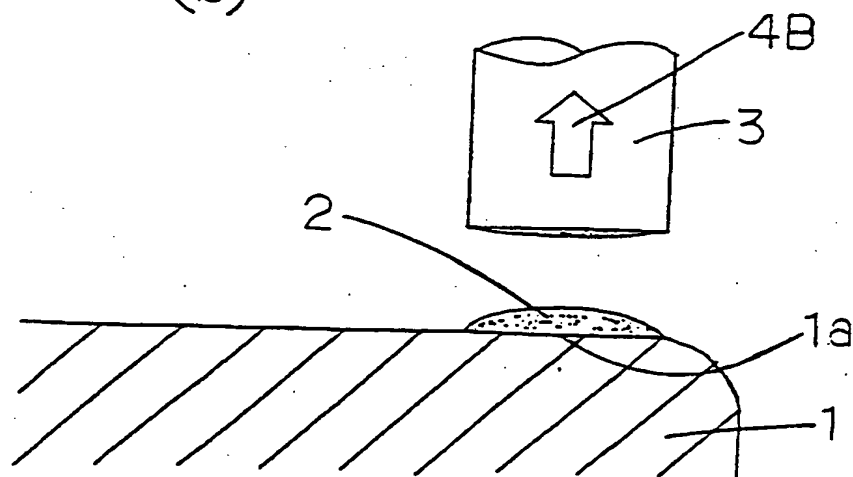
Drawings

Fig. 1

(a)



(b)



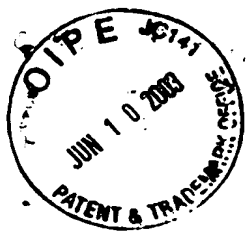


Fig. 2

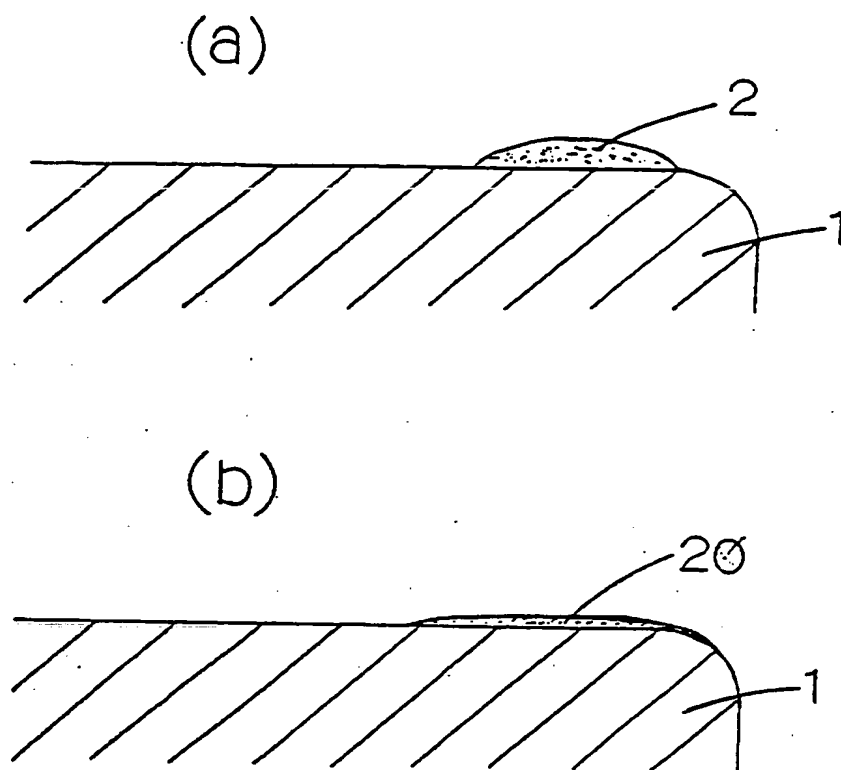
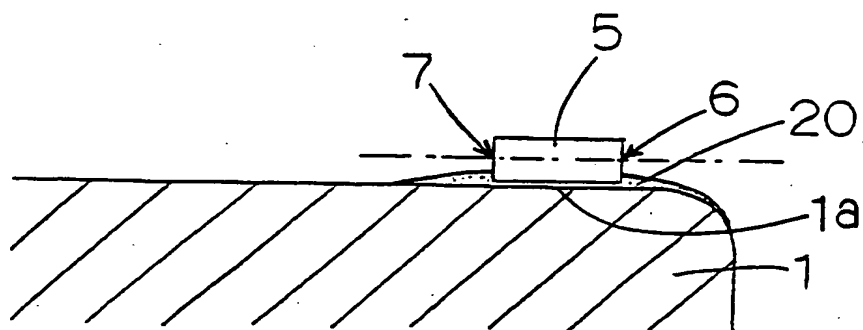


Fig. 3





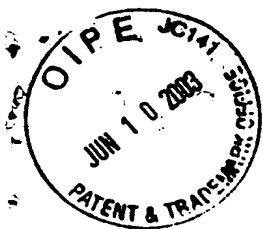
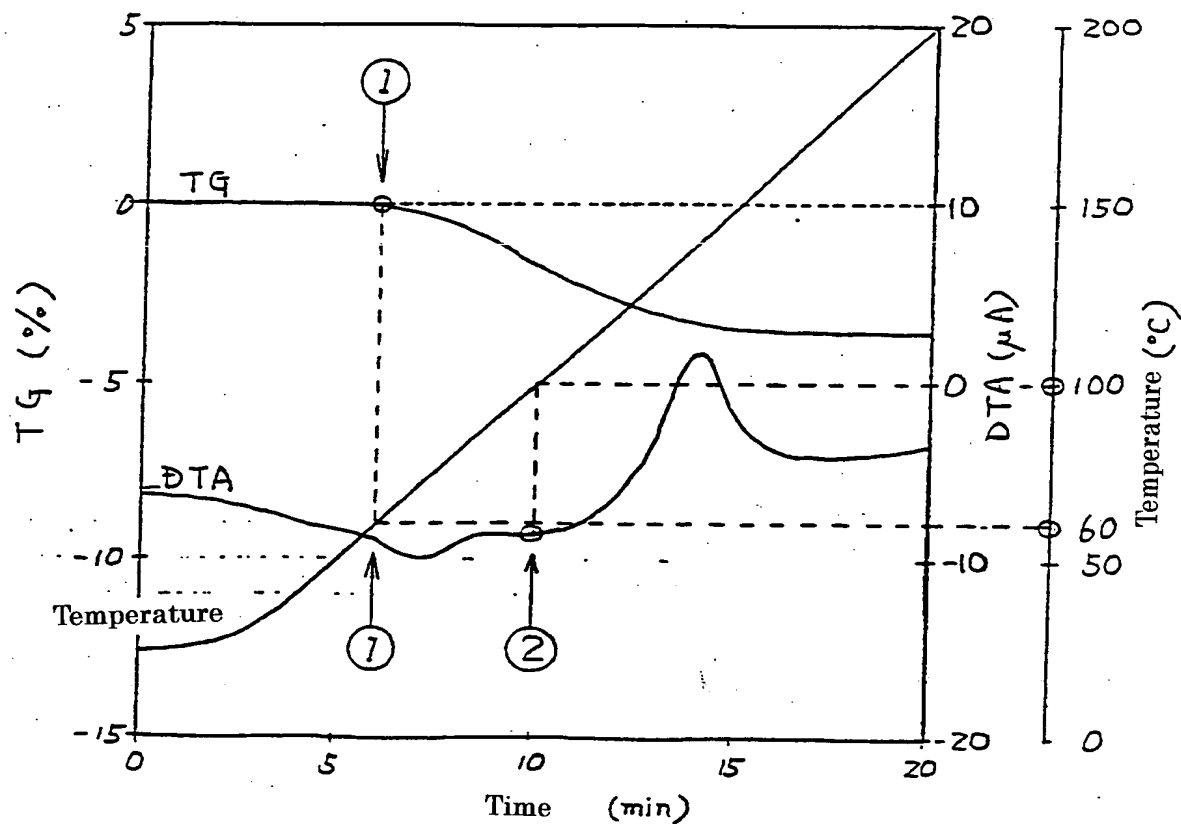


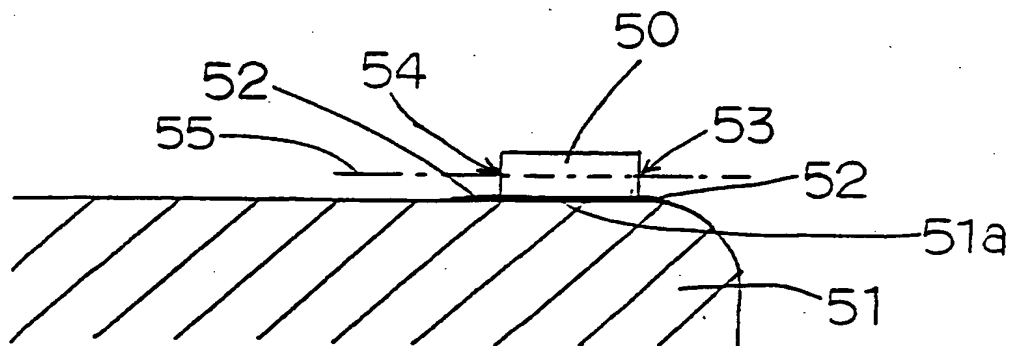
Fig. 4



① : A diluent starts to transpire (60°C).

② : A thermosetting reaction of resin starts (100°C).

Fig. 5



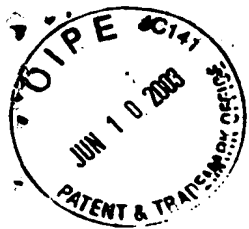


Fig. 6

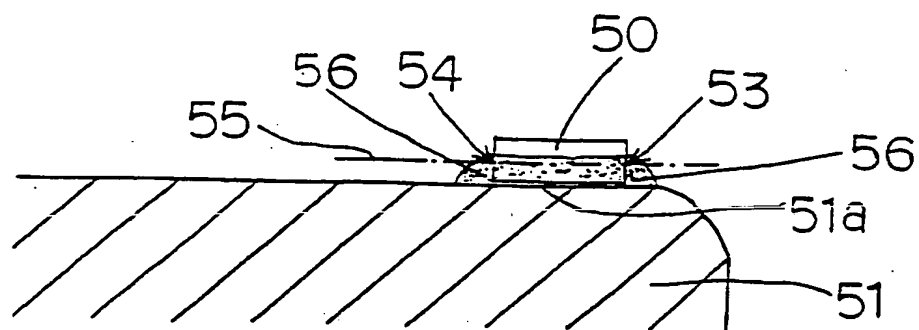
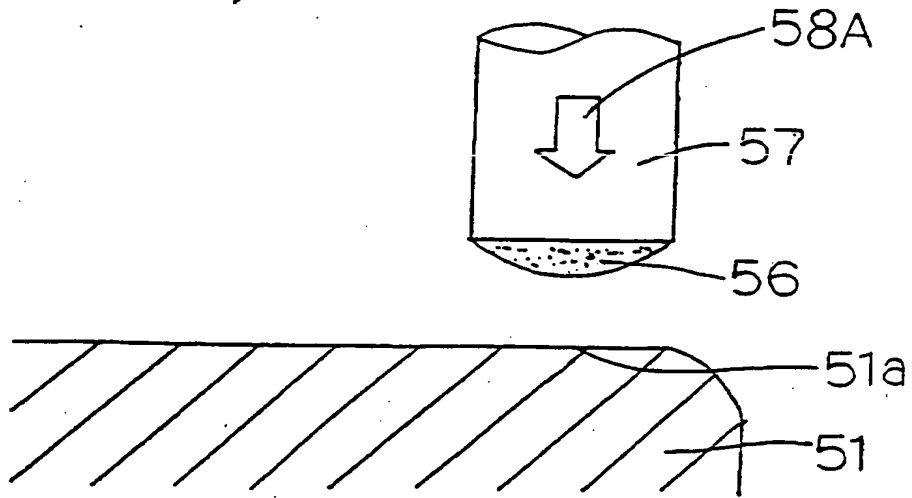
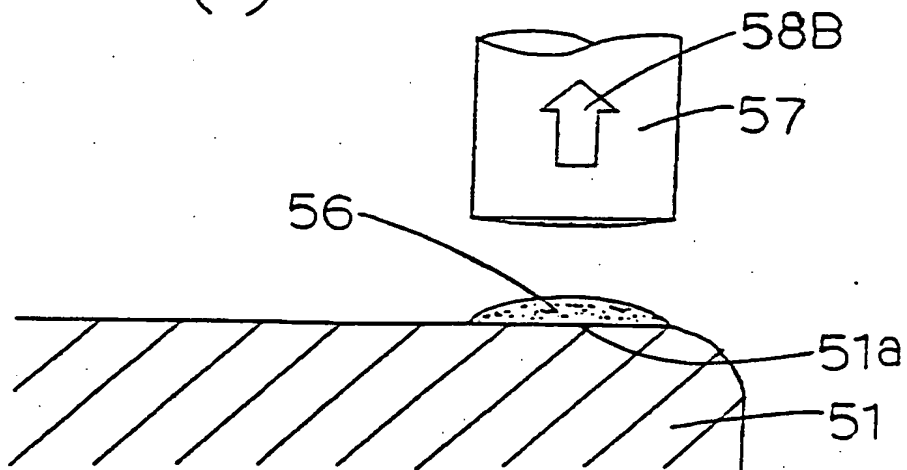


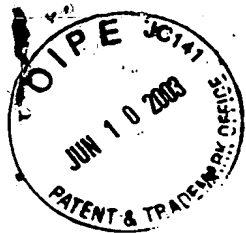
Fig. 7

(a)



(b)





Document name: Abstract

Summary:

Object: To provide a semiconductor laser apparatus, which prevents a conductive die-bonding paste, if used, from blocking light-emitting points of a semiconductor laser chip in the process of die-bonding the semiconductor laser chip to a stem and so on, and which does not cause regular reflection in the case where it is used for a pick-up using a three-beam scheme, and a method of producing the same.

Solution: In die-bonding a semiconductor laser chip to a stem and the like, a conductive die-bonding paste containing an epoxy resin as a base material is adopted, and is applied to the stem and the like. Then, immediately before mounting a semiconductor laser chip on the applied conductive die-bonding paste, the applied die-bonding paste is preheated at a temperature lower than a temperature at which the conductive die-bonding paste starts a thermosetting reaction. By setting a temperature at which the conductive die-bonding paste is preheated to equal to or higher than a temperature at which a diluent of the conductive die-bonding paste starts to transpire, but not exceeding a temperature at which the conductive die-bonding paste starts a thermosetting reaction, and a heating time to two seconds or more, the viscosity of the conductive die-bonding paste is reduced. A position at which the conductive die-bonding paste adheres to is at a height of more than 0.01 mm from a die-bonding surface, but is below the light-emitting point of the semiconductor laser chip.

Selected figure: Fig. 3